AF/SA

ALL WEATHER

WHAT DOES IT MEAN ?

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Historically, many military tacticians recognized the impact weather can have on the conduct of military operations. As early as 480 B.C., the Greeks exercised their knowledge of strong sea breezes to defeat the Persians in the Battle of Salami. Hannibal used his superior knowledge on the timing of the spring thaw in the Appennine Passes north of Genoa to strategically position his army between the Roman Armies and their capital.[1]

During World War II weather played an important role in both the European and Pacific theater. Since aircraft were flying higher, faster, and farther than before, they encountered meteorological phenomena, such as jet stream winds and extremely cold temperatures that froze lubricants, which they had not experienced before. General Eisenhower readily recognized that "in Europe bad weather was the worst enemy of the air."[2]

Almost twenty years of technological evolution had transpired when the Southeast Asian Conflict reached its peak. Still the Navy's A-6 and the Air Force's B-52 and F-111 were the only aircraft that even approached an "all-weather" capability. The so-called "smart" bombs, Electro-Optical Ordnance, could be categorized as "smart" when launched only in the absence of weather.[3] During the "Linebacker II" exercise in December 1972, Admiral Moore testified[4] that there were actually only about 12 hours (in a 11 day conflict) which were suitable for visual bombing, including use of the so-called "smart" bombs.

Because tacticians and weapons planners have recognized the importance of weather to military operations, they have long sought to achieve an "all-weather" capability. But what does an "all-weather" capability really mean? This paper will discuss some conceptual views of "all-weather" capabilities and then address potential system utility based on the occurrence, duration, and distribution of weather in a Central German scenario.

The impact weather can exert is a function of many other variables such as the mission to be performed, the system being used, the arena in which the mission is performed, the tactics used, and such. For example, an aircrew flying air-to-air combat missions would be less concerned with the cloud and visibility conditions in the lowest 500 feet of the atmosphere than an aircrew flying close air support or battlefield interdiction missions. To the air-to-air combatant, information like the location of cloud tops, presence of clear layers, and coloration of the sky can be critical. If this is true, then what is meant by the term, "all-weather?"

The term "all-weather" connates different things to different people. Air Force Manual 11-2[5] recognizes two Department of Defense acceptable definitions in reference to weather: All-Weather Fighter and Adverse Weather. Adverse weather is weather in which military operations are generally restricted or impeded. This definition could include almost any weather phenomena since it encompasses naval, ground, and air operations.

An "all-weather" fighter is a fighter aircraft with radar devices and other special equipment which enable it to intercept its target in dark ot daylight weather conditions which do not permit visual interception. Here "all-weather" is relegated to detection/acquisition process. Weather phenomena such as turbulence, icing, etc., would only be indirect considerations when they affect visual interception. Many definitions and concepts in the Air Force follow similar lines.

Prior to October 1978, the Air Force Planning Guide[6] listed the definitions in Table 1 in the section on Theater Conflict. Notice that the 1500 foot and 3 mile condition also coincides with the visual/instrument flight rule delineation. In the October 1978 version of the Guide, the ceiling/visibility conditions were deleted in favor of a definition of "all-weather" more closely associated with our definition of "All-Weather Fighter." However, within the new Guide itself, there is no consistent definition. For example, the section on Command and Control lists conditions below 500 feet and 2 miles as "all-weather" which is quite different from the definition in the section on Theater Conflict.

The Non-Nuclear Consumables Analysis[7], Table 1, lists six categories of weather conditions with ceilings from 500 feet through 12,000 feet and visibilities from 3 miles to 5 miles. Although there is no distinction made for "all-weather", conditions below 500 feet and/or 3 miles would be for non-visual flight rule delivery.

TABLE 1. CURRENT ALL-WEATHER CONCEPTS

- AIR FORCE PLANNING GUIDE:

DAY/NIGHT CLEAR	GREATER THAN 3000 FT/5 MILES
DAY/NIGHT ADVERSE	BETWEEN 3000 FT/5 MILES AND 1500 FT/3 MILES
ALL WEATHER	LESS THAN 1500 FT/3 MILES

- NON NUCLEAR CONSUMABLES ANNUAL ANALYSIS:

CATEGORY	CEILING VISIBILITY CONDITIONS
1	≥ 500 FT/3 MILES BUT < 1000 FT/3 MILES
2	≥ 1000 FT/3 MILES BUT < 1500 FT/3 MILES
3	≥ 1500 FT/3 MILES BUT < 3000 FT/4 MILES
4	≥ 3000 FT/4 MILES BUT < 6000 FT/5 MILES
5	≥ 6000 FT/5 MILES BUT < 12000 FT/5 MILES
6	≥ 12000 FT/5 MILES

- OFFENSIVE AIR SUPPORT MISSION ANALYSIS:

DAYTIME	— LUMINESCENCE AND WEATHER CONDITIONS PERMIT USE OF VISUAL SYSTEMS
NIGHTTIME	— LUMINESCENCE AND WEATHER CONDITIONS PRECLUDE USE OF VISUAL SYSTEMS BUT PERMIT INFRARED (IR)
ADVERSE	— LUMINESCENCE AND/OR WEATHER CONDITIONS PRECLUDE USE OF VISUAL AND IR SYSTEMS

- GENERAL OPERATIONAL REQUIREMENT FOR AUTONOMOUS TACTICAL ALL WEATHER STRIKE:
  - ALL WEATHER DEFINED AS ZERO-ZERO TO CLEAR. RAIN RATES SPECIFIED.

- OTHERS
  - NON-NUCLEAR ARMAMENT PLAN
  - TACTICAL ALL WEATHER ATTACK REQUIREMENTS
  - MISSION ELEMENT NEED STATEMENT FOR ENHANCED TACTICAL FIGHTER
  - JOINT MISSION ELEMENT NEED STATEMENT FOR TACTICAL AIR DEFENSE SUPPRESSION
  - JOINT CLOSE AIR SUPPORT/INTERDICTION MISSION AREA ANALYSIS AND MISSION ELEMENT NEED STATEMENT

The Offensive Air Mission Analysis[8] (OASMA) has several references to day/night and adverse weather. The most general references occur in Section IV.H.2 of the main report and are listed in Table 1. More specific ceiling and visibility can be found for the OASMA study in other sections of the report. And, as Table 1 implies, there are other plans, requirements, etc., which reference "all-weather." The only consistency which is apparent in these references is that they predominantely address "all-weather" in terms of ceiling and visibility.

The meteorologists perception of "all-weather" is somewhat different in that he views it as a totally inclusive term comprised of all possible meteorological phenomena which might impact a system. The weatherman would be concerned not only with system susceptibility to ceiling and visibility but also to icing, turbulence, etc., as seen in Figure 1. There are times when these other phenomena can be as critical or even more critical than ceiling and visibility constraints when addressing "all-weather" capabilities.

- WEATHER CONDITIONS
  - CEILING
  - VISIBILITY
  - HUMIDITY
  - TEMPERATURE
  - PRECIPITATION
  - WINDS
  - TURBULENCE
  - ICING
  - THUNDERSTORMS
  - HAIL
  - FREEZING PRECIPITATION

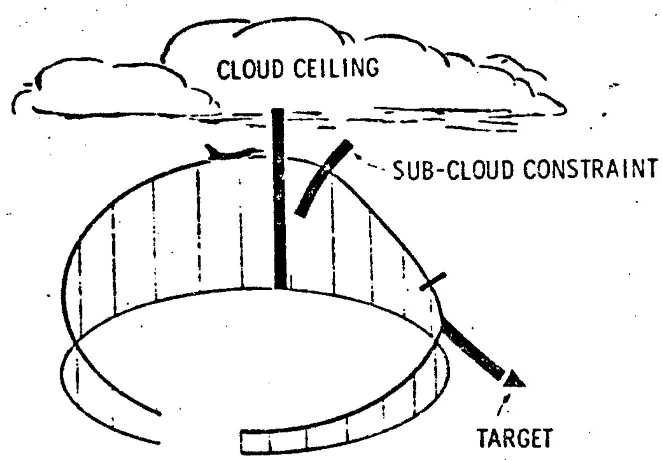

FIGURE 1. METEOROLOGIST CONCEPT OF "ALL WEATHER"

Icing is a condition which can affect any system performance, however, it can be very critical to a slow, low flying aircraft during a European winter. Winter climatological records for several German locations indicate that 20 to 30 percent of the time precipitation is occurring.[9] Most of it occurs as rain, drizzle, snow, or sleet. However, only about two percent of the time can freezing rain or drizzle be expected to occur. Most precipitation is accompanied by thick clouds in which the possibility of some icing can be anticipated. Icing conditions of some form can be expected to occur 15 to 20 percent of the time in Germany in the winter.[10] The type and intensity of icing is dependent on the amount of moisture available, temperature, collection efficiency of the weapons systems, speed of the systems and such.

Thunderstorms are another meteorological phenomena which can impact system performance. Thunderstorms can have other phenomena associated with their occurrence such as hail, lightning, turbulence, icing, and reduced visibility in cloud or precipitation. Heavy precipitation from such storms have been known to cause compressor stalls in modern jet engines due to excessive water injestion. Lightning strikes are especially hazardous to aircraft constructed of composite materials because the damage due to such strikes is more extensive than with the old aluminum skinned aircraft. During the early summer in Germany, thunderstorms can be expected to occur one to two percent of the time.[11]

Modern electro-optical (E-O) weapons systems operating in the visual through millimeter wavelengths have highlighted the importance of environmental parameters which previously received secondary considerations. The atmosphere can have an indirect, as well as a direct, impact on E-O systems through interactive effects on a background contrast which is a major factor in E-O system performance. This situation was exemplified in the Joint Operational Test and Evaluation (JOT&E) of the Imaging Infrared (IIR) Maverick Missile in February 1977 at Folk Polk, Louisiana and in the Initial Operational Test and Evaluation (IOT&E) of the IIR Maverick in February 1978 at Baumholder, Federal Republic of Germany.

A minor drought condition in the southern U.S. during the JOT&E caused the coniferous trees in the area to be "stressed." The stressed trees attempted to retain what water they had by reducing their transpiration. This caused the temperature of the trees to increase and appear warmer through the infrared sensor causing considerable clutter in the video display. When the tanks or APC's were amongst the trees they were more difficult to detect than when they were contrasted against the ground.

During one day of testing at the IOT&E, strong insolation heated cleared roads which were bounded by snow cover. The result was a large thermal contrast (ΔT) between the road surface and the cold snow. This set the threshold temperature within the missile at a level such that,

when vehicles riding down the road were attacked with the IIR Maverick, the seeker gate would expand to be filled by the hot road and not only the vehicle. These secondary atmospheric effects can definitely have an impact on the adverse weather capability of a system.

There are many other weather parameters which can have a variety of impacts on systems depending on the mission the system is performing. The point to be made here is that it may be very misleading to assess a system's "all-weather" capability in terms of ceiling and visibility restrictions alone. Also, with the variety of definitions for "all-weather" that exists, it is becoming difficult to make comparisons of utility between competing systems. It appears that the most effective solution to the situation might be to develop some general guidelines, based on mission or function of the system, which constitute a standard definition of "all-weather."

From experience, we know that the more stringent we make our weather requirements the more enhanced our system must be to operate in those weather conditions. The more enhanced our systems become, the more costly they are. We might then ask "Is the expense required to achieve an 'all-weather' capability worth the cost?" Using data available on the spatial and temporal variability of meteorological phenomena, the effects of weather on system utility can be investigated.

Meteorological parameters like clouds and visibility show variability in space and time. To demonstrate this phenomena, cloud information, for the 15 locations in Figure 2, was extracted from the Air Weather

Service 3-Dimensional Nephanalysis (3D NEPH) data base.[12] Each grid

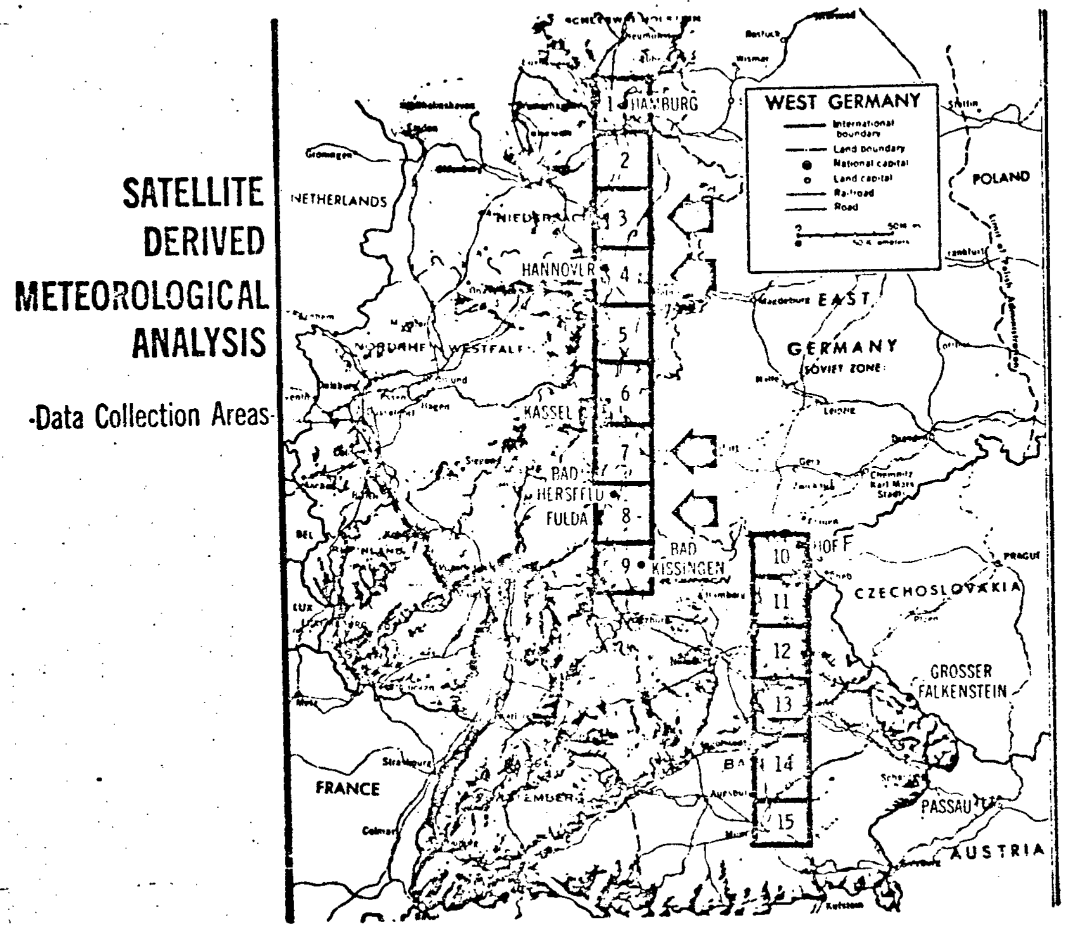

FIGURE 2. CENTRAL GERMAN 3D-NEPH LOCATIONS

square is 25 nautical miles on a side. The month of January was selected as representative of a winter cloud situation. The year 1974 was chosen because our analysis, depicted in Figure 3, indicated that it was an average year.

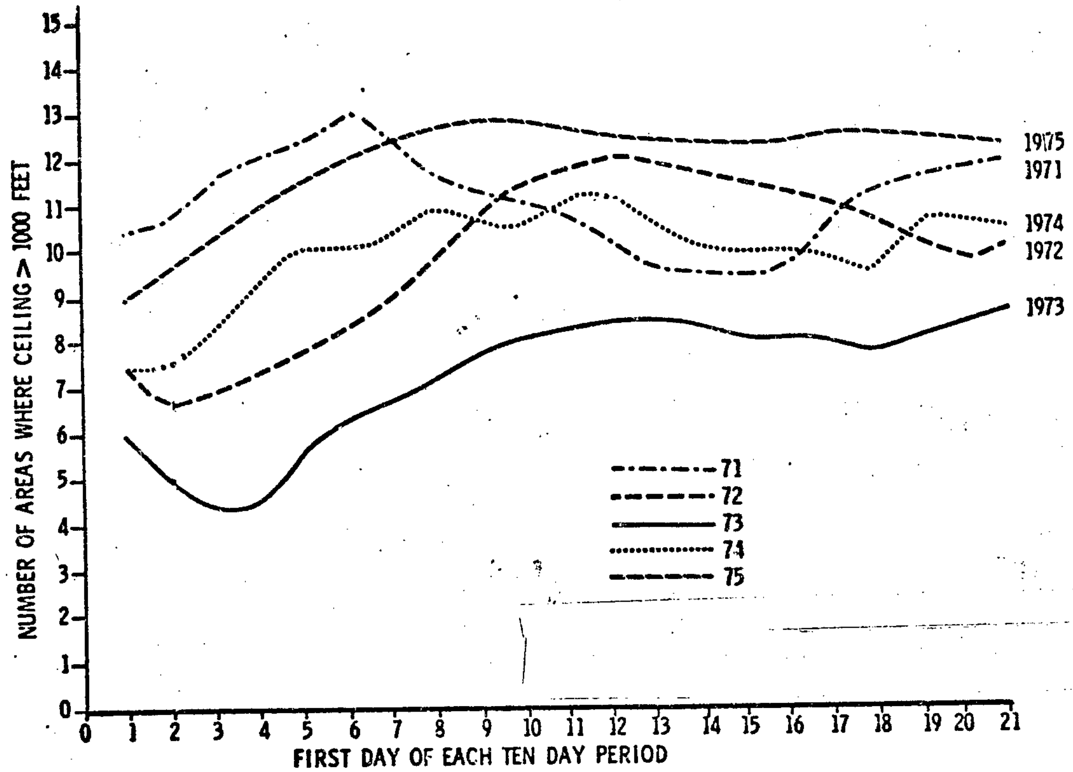

FIGURE 3. AVERAGE NUMBER OF AREAS WITH CEILING ABOVE 1,000 FEET FOR 10 DAY PERIOD IN JANUARY

A time cross-section for the 15 locations in Figure 2 is shown in Figure 4. The hatched areas show when ceilings were below 1000 feet above ground level. It is obvious that clouds vary both in time and space. This sort of data is important in demonstrating that there are always areas of decent weather conditions even though the weather at one location is bad. Figure 5 shows the monthly area to area correlation which indicates that there is generally poor correlation between areas as close as 25 nautical miles.

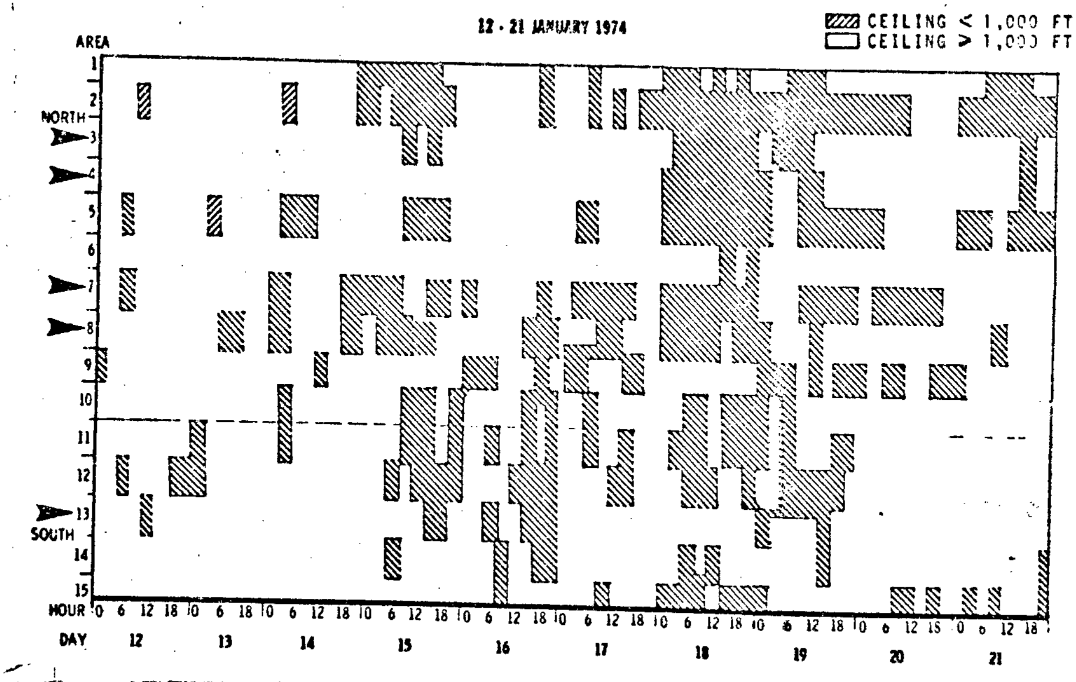

FIGURE 4. CEILING CONDITIONS ALONG A FRONT IN WEST GERMANY

(JANUARY 1974)

LOCATION	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	1.														
2	.70	1.													
3	.75	.63	1.												
4	.54	.36	.63	1.											
5	.31	.36	.32	.38	1.										
6	.39	.29	.46	.46	.46	1.									
7	.52	.46	.54	.37	.33	.37	1.								
8	.49	.13	.09	-.12	.03	.00	.43	1.							
9	.17	.11	.14	.04	.13	-.11	.11	.25	1.						
10	.30	.23	.26	.12	.08	.16	.27	.33	-.05	1.					
11	.31	.22	.29	.07	.06	.15	.23	.31	.09	.80	1.				
12	-.03	.21	.05	-.05	-.12	-.09	.20	.50	.02	.20	.13	1.			
13	-.10	-.04	.00	-.31	-.11	-.13	.18	.41	.08	-.03	.10	.44	1.		
14	.12	.00	.19	.04	-.03	.12	.22	.24	-.14	.14	.15	.11	.49	1.	
15	.19	.05	.22	.26	.08	.32	.22	.00	-.18	.20	.12	.03	-.03	.31	1.

FIGURE 5. CORRELATION COEFFICIENTS BETWEEN NORTH-SOUTH LOCATIONS IN GERMANY

A similar situation exists vertically in the atmosphere as Figures 6 through 8 indicate. These time-sequenced, vertical cross-sections for the 15 German locations show that even in heavily clouded areas there are still clear layers available for possible visual air-to-air activities. Therefore, it is incorrect to state a requirement for an "all-weather" system based on the assumption that, when the weather degrades, it is bad everywhere.

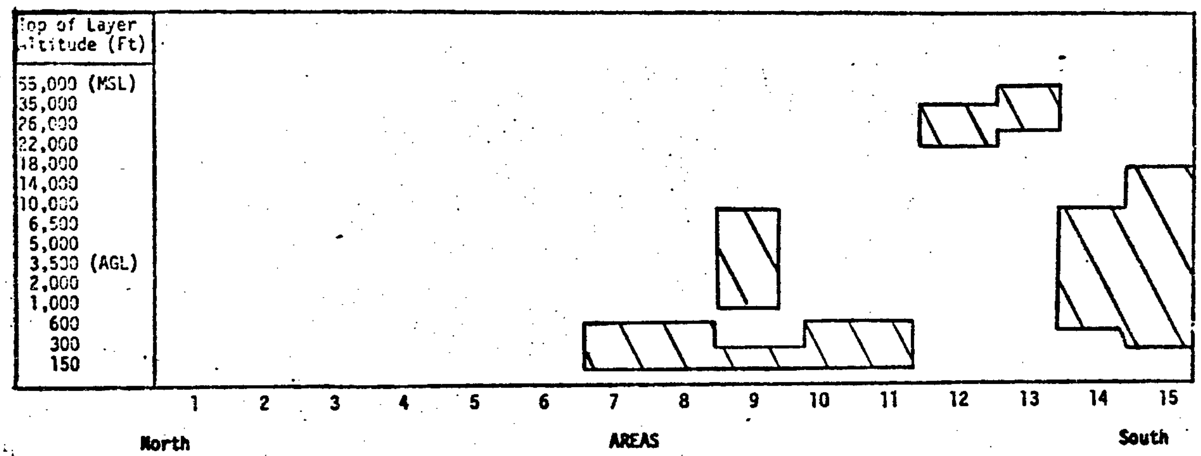

FIGURE 6. NORTH-SOUTH CROSS SECTION THROUGH WEST GERMANY FOR 30 JANUARY 1974 AT 0900Z. CROSS-HATCHED AREA DEPICTS 30 PERCENT CLOUD COVER OR GREATER.

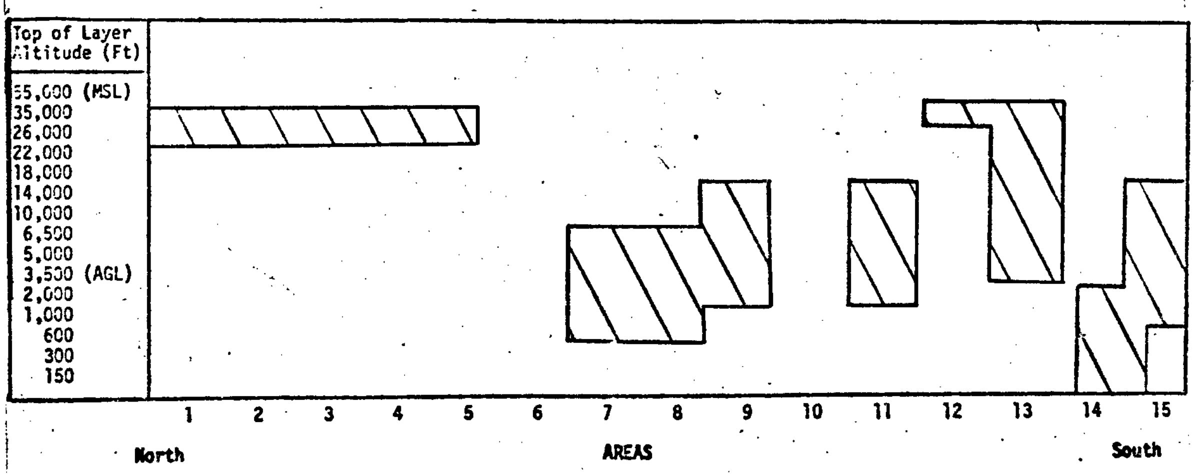

FIGURE 7. NORTH-SOUTH CLOUD CROSS SECTION THROUGH WEST GERMANY FOR 30 JANUARY 1974 AT 1200Z. CROSS-HATCHED AREA DEPICTS 30 PERCENT CLOUD COVER OR GREATER.

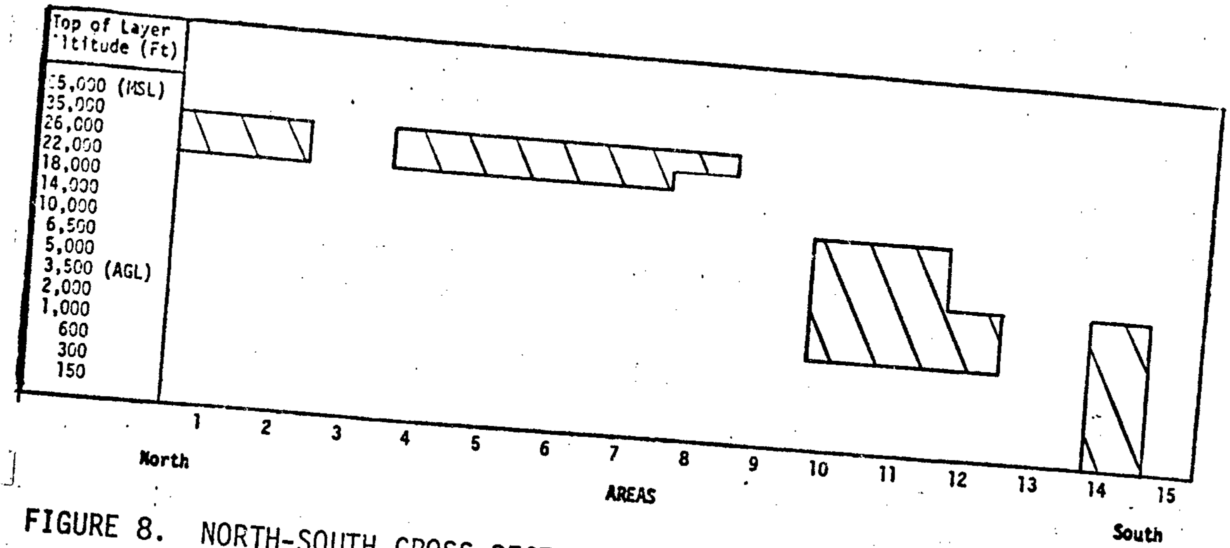

FIGURE 8. NORTH-SOUTH CROSS SECTION THROUGH WEST GERMANY FOR 30 JANUARY 1974 AT 1500Z. CROSS-HATCHED AREA DEPICTS 30 PERCENT CLOUD COVER OR GREATER.

At times, however, it may be necessary to conduct operations in a specific location at a given time. Then the spatial variability discussed above no longer affords the commander the ability to select the least weather restricted target area. Considerations are consequently reduced to the frequency of occurrence and duration of the critical meteorological parameters at a single location. Even when the problem is reduced to this situation, there are some interesting aspects as to what is gained in terms of utility as we progress to lower ceiling and visibility categories.

To demonstrate how weather conditions can look at a single location, three different stations were selected for the analysis: Bitburg AFB, Hannover, and Grafenwohr in the Federal Republic of Germany.[13] Depcited in Figures 9 through 11 are the percent frequencies of occurren[illegible] of ceiling/visibility conditions at the three locations. Notice th[illegible] the variation in visibility for a given ceiling is greater than [illegible] variation in ceiling for a given visibility. Conditions belo[illegible]

and/or 2 miles can be expected about one-third of the time and below 300 feet and/or 1 mile can be expected between 9 and 16 percent of the time.

HANNOVER
JANUARY
(CONDITIONS LESS THAN)

VISIBILITY (MILES)	CEILING (FEET)				
	1000	500	300	200	100
4	66	63	63	63	63
3	50	45	44	44	44
2	42	34	32	32	32
1	28	14	9	7	7
1/2	25	10	5	2	2

FIGURE 9. HANNOVER CEILING/VISIBILITY PERCENT FREQUENCY OF OCCURRENCE.

BITBURG
JANUARY
(CONDITIONS LESS THAN)

VISIBILITY (MILES)	CEILING (FEET)				
	1000	500	300	200	100
4	50	44	43	43	43
3	45	37	36	36	36
2	39	28	25	25	25
1	34	19	16	13	13
1/2	33	18	11	10	9

FIGURE 10. BITBURG CEILING/VISIBILITY PERCENT FREQUENCY OF OCCURRENCE.

GRAFENWOHR
JANUARY
(CONDITIONS LESS THAN)

VISIBILITY (MILES)	CEILING (FEET)				
	1000	500	300	200	100
4	64	62	62	62	62
3	56	52	52	52	52
2	40	33	32	32	32
1	28	15	13	13	13
1/2	25	8	5	4	4

FIGURE 11. GRAFENWOHR CEILING/VISIBILITY PERCENT FREQUENCY OF OCCURRENCE (POR 1959-1969)

Figures 9 through 11 are compiled for all hours. To consider daylight only systems one would have to multiply these probabilities by 0.33 for the winter case (actually 0.25 in December and 0.375 in February) to get daylight probabilities. Also it is entirely feasible to encounter other critical weather parameters with these ceiling/visibility conditions, like icing and turbulence, which are not considered in these data. What these charts do allude to is that the costs expended to achieve a capability in lower ceiling/visibility conditions return smaller percentage of time as we proceed to lower and lower conditions.

If potential system utility is assessed on a basis of ceiling/visibility constraints and day/night capabilities, some interesting insights can be obtained. In Figure 12, for example, if a conceptual system has capability in the daytime only and requires a ceiling/visibility condition of 1000 feet and/or 4 miles or greater, the potential utility

is about 10 percent during January and 55 percent in July. The addition of a night capability alone increases the potential utility to 32 percent in January and 81 percent in July. Being able to work in visibilities down to two miles, increases the utility to 58 percent in January and 93 percent in July. A system which can function down to conditions of 500 foot ceilings and/or 1 mile visibilities (day and night) brings the potential utility up to 86 percent in January and 98 percent in July.

Somewhat better but similar information would apply to Grafenwohr, Figure 13, as was shown for Hannover, Figure 12. One fact these Figures point out is that we realize the largest payoff by acquiring a day and night capability, especially in winter. Achieving a nighttime capability improved our potential utility by a factor of three during the winter; whereas, going from a 1000 foot and/or 2 mile capability to a 500 foot and/or 1 mile capability showed only a 1.3 potential improvement. And in the summer, these improvements are drastically reduced.

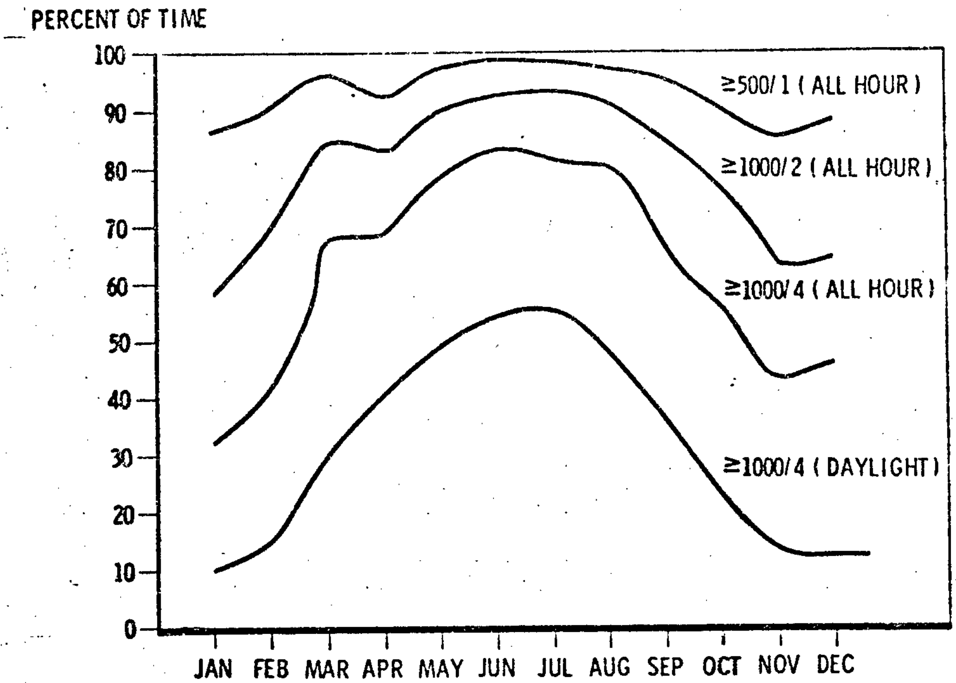

FIGURE 12. POTENTIAL SYSTEM UTILITY FOR HANNOVER (POR: 1965-1971)

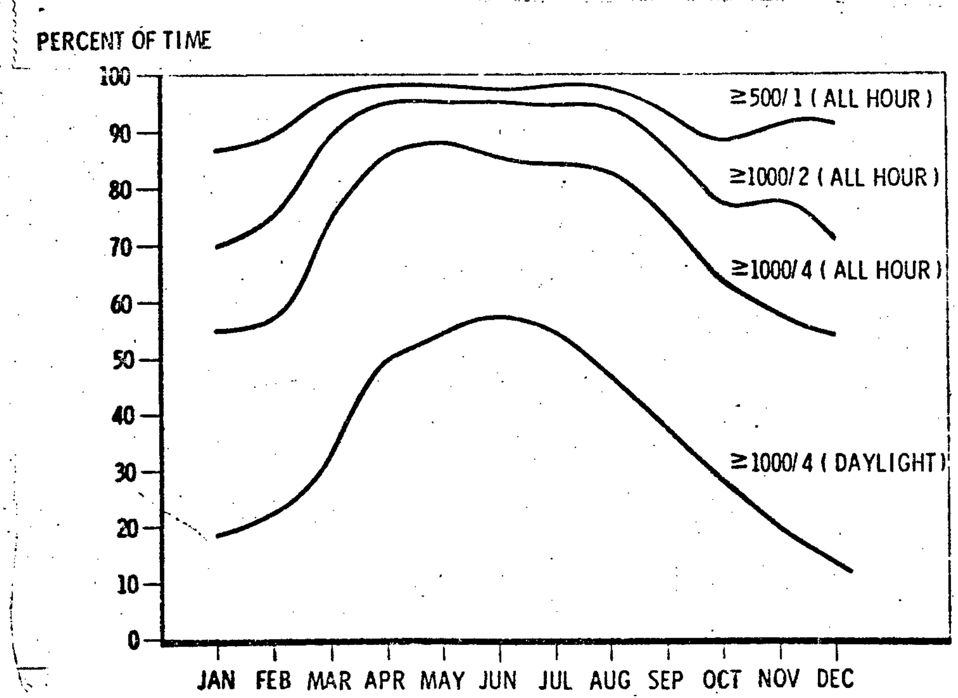

FIGURE 13. POTENTIAL SYSTEM UTILITY FOR GRAFENWOHR (POR: 1973-1976)

Before going any farther, one note of caution needs to be discussed. The period of record (POR) for a climatological data sample is critical to the distributions. If a 10 year data base for Grafenwohr, Figure 11, is compared to a three year data base for Grafenwohr, Figure 14, significant differences can be observed. The shorter POR, Figure 14, is much more optimistic than the ten year POR, Figure 11, especially when the visibility is two miles or better. For conditions of 100 feet and/or 2 miles through 500 feet and/or 2 miles, the three year POR is more than a factor of two more optimistic than the ten year POR. For the most accurate climatological analysis, the POR should be at least 10 years or longer.

GRAFENWOHR
JANUARY
(CONDITIONS LESS THAN)

VISIBILITY (MILES)	CEILING (FEET)				
	1000	500	300	200	100
4	45	40	40	40	40
3	35	26	25	25	25
2	30	18	17	17	17
1	27	13	10	10	10
1/2	26	11	7	6	6

FIGURE 14. GRAFENWOHR CEILING/VISIBILITY PERCENT FREQUENCY OF OCCURRENCE.

In many instances, the fact that a given weather situation has occurred may not be as important as how long the condition persists given that it has occurred. This information can be obtained by performing a duration analysis.[14] Figure 15 depicts the probability of occurrence of a given duration (hours) for four ceiling/visibility conditions. These data, from Grafenwohr in January, indicate that conditions below 200 feet and/or 1 mile would most likely last three to four hours. However, conditions below 500 feet and/or 3 miles can be expected to last on an average of nine to ten hours.

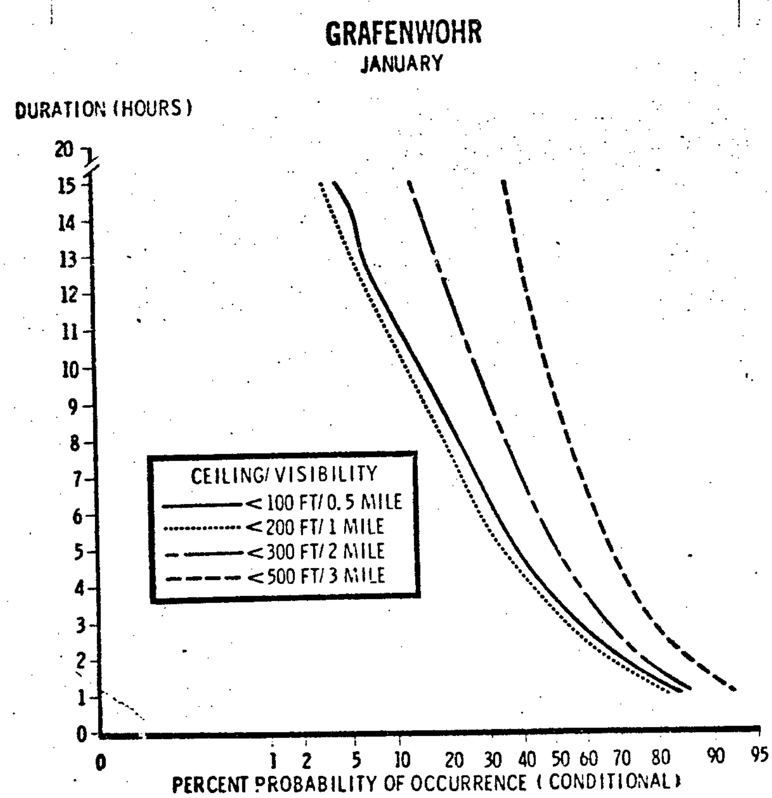

FIGURE 15. DURATION OF CEILING/VISIBILITY CONDITIONS

Figure 16 attempts to again address the fact that the weather is not the same at different locations. For a condition of 500 feet and/or 3 miles, duration are plotted for the three German locations. Grafenwohr has the longest durations of poor weather of the three. There can be as much as a 10 percent difference between Bitburg and Grafenwohr for a given duration. This chart does help stress the fact that it is imprecise to select one location and state that its weather is "typical" of a whole region.

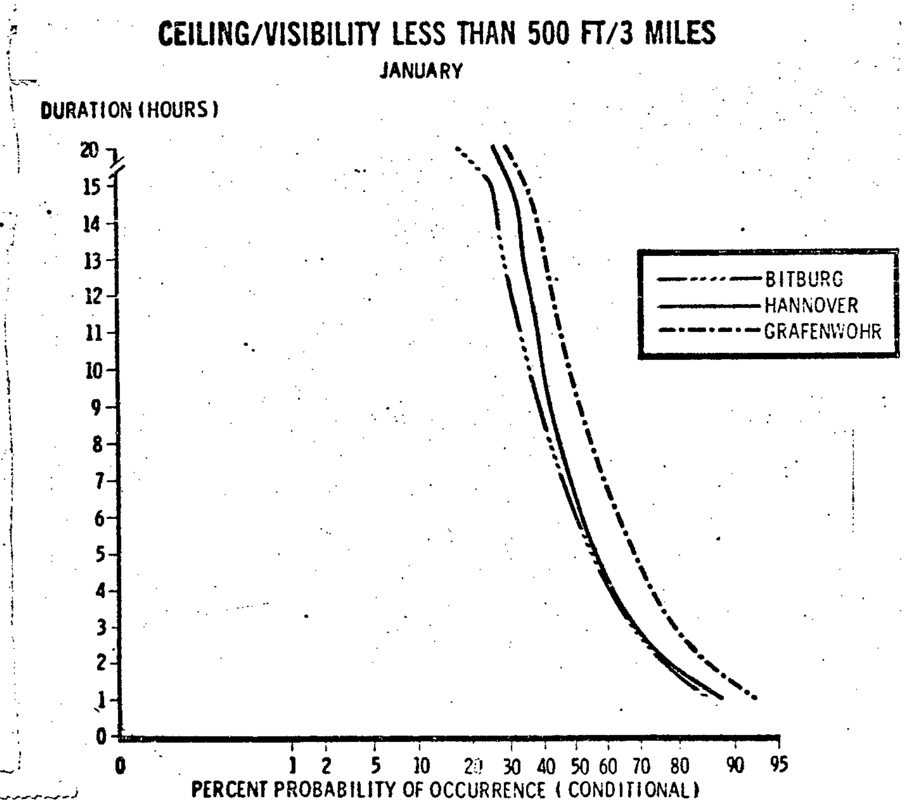

FIGURE 16. DURATION OF CEILING/VISIBILITY CONDITIONS FOR THREE GERMAN LOCATIONS.

As pointed out in the beginning, there is no clear cut, universally accepted definition of the term "all-weather." To eliminate confusion when comparing different "all-weather" systems and to be consistent in our understanding of the concept of "all-weather", standard definition, based on mission, should be developed. Also, it is not advisable to relegate the definition of "all-weather" to ceiling/visibility definition alone. Other factors, like icing and turbulence, may have a significant impact on system performance.

In expending resources to achieve an all weather capability, we should be cognizant of the payoffs to be derived. The mission requirements will most often drive the problem. If we are afforded the opportunity to attack more than one area, the spatial and temporal distribution of weather may permit the use of less sophisticated systems (in the better weather areas). However, if our systems must be employed in one location at a particular time, more elaborate systems may be required (during poor weather). Good information on the frequency of occurrence and duration of critical weather parameters may be useful in determining the cost effectiveness of a specific system.

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